Upper Sacramento River Winter Chinook Salmon Carcass Survey 2002 Annual Report

A U.S. Fish & Wildlife Service Report

Annual Report to

California Bay-Delta Authority
Ecosystem Restoration Program
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Abstract

The U.S. Fish & Wildlife Service conducts a supplementation program for winter Chinook salmon, an endangered species, at the Livingston Stone National Fish Hatchery. Since 1996, the U.S. Fish & Wildlife service and the California Department of Fish and Game have cooperated on an annual survey of winter Chinook salmon returning to the upper Sacramento River (Upper Sacramento River winter Chinook salmon carcass survey). Provided in this report is a summary of the 2002 upper Sacramento River winter Chinook salmon carcass survey, including: (1) an evaluation of the winter Chinook salmon supplementation program at the Livingston Stone National Fish Hatchery, and (2) genetic run identification of the spawning population.

Survey results indicate that 921 hatchery winter Chinook salmon returned to the Upper Sacramento River in 2002. Escapement of winter Chinook salmon in 2002 increased by 796 as a result of the winter Chinook salmon supplementation program at Livingston Stone NFH. Recoveries of hatchery carcasses included several coded wire tag codes indicating that hatchery winter Chinook salmon contained several different family groups and likely maintained the genetic diversity of their parent stock. Carcasses of hatchery and natural winter Chinook salmon were observed at similar times, suggesting similar spawn timing. Adult hatchery males were smaller than adult natural males; however, no fork length differences existed among hatchery and natural grilse males, grilse females, and adult females. The proportion of hatchery males returning as grilse was greater than natural males but this difference was not observed for females. Compared to natural winter Chinook salmon, hatchery fish returned in smaller proportions as males, but considerably more females were recovered overall for both hatchery and natural fish. Hatchery and natural winter Chinook salmon were generally observed in similar locations, however hatchery fish had a propensity to be distributed further upstream, closer to the Livingston Stone National Fish Hatchery. Hatchery and natural females appeared to have equal spawning success. Genetic analysis and numbers of carcasses recovered each survey period indicate that the winter Chinook carcass survey adequately surveyed the winter Chinook salmon spawning population in the upper Sacramento River.

Introduction

In 2002, the U.S. Fish and Wildlife Service (Service) and the California Department of Fish and Game (CDFG) conducted a survey for adult winter Chinook salmon *Oncorhynchus tshawytscha* carcasses in the upper Sacramento River. Primary objectives of the upper Sacramento River winter Chinook salmon carcass survey (carcass survey) were to (1) collect information on several important life history attributes of winter Chinook salmon, including: age and gender composition of the spawning population, pre-spawning mortality rate, and temporal and spatial distribution of spawning, (2) collect data useful to evaluate the winter Chinook salmon supplementation program at the Livingston Stone National Fish Hatchery (NFH), and (3) estimate the abundance of winter Chinook salmon returning to the upper Sacramento River. The following report is submitted to satisfy annual requirements of the Service, including objectives one and two. A complimentary report will be generated by the CDFG to address objectives one and three. Together, these reports will satisfy the reporting responsibilities for the second year of this project funded by the California Bay-Delta Authority, formerly CalFed.

Background

The Sacramento River supports four distinct "runs" of Chinook salmon: fall, late-fall, spring, and winter. Winter Chinook salmon begin their freshwater migration from November through June in an immature reproductive state. They migrate into the upper reaches of the Sacramento River, hold in cool waters released from Shasta Dam, and spawn from May through August between the city of Red Bluff and the Keswick Dam (the upper limit of migration). Most winter Chinook salmon spawn at age 3, with the remainder spawning at ages two and four (Hallock and Fisher 1985; Fisher 1994). Virtually all of the grilse (age 2) are precocious males, commonly known as "jacks."

Winter Chinook salmon have been listed as endangered under the Endangered Species Act since 1994 (59 Federal Register 440) due to a small abundance of returning adults and a declining population trend (Figure 1). In 1989, the Service began propagating winter Chinook salmon to supplement natural production and to protect against extinction. The winter Chinook supplementation program was initially located at the Coleman NFH on Battle Creek, a tributary of the Sacramento River. In 1998, the program was moved to a new facility at the base of Shasta Dam, Livingston Stone NFH, to improve imprinting to the mainstem Sacramento River.

A draft recovery plan for Sacramento River winter Chinook salmon was developed in 1997 by the National Marine Fisheries Service (1997). The draft recovery plan specified delisting criteria that requires a mean annual spawning abundance of 10,000 females and a cohort replacement rate greater than one over 13 consecutive years. The recovery plan also stipulated that in order to evaluate progress toward these delisting goals a monitoring system must be in place to estimate abundance of spawning winter Chinook salmon with an estimation error less than 25%. Beginning in 1996 the Service and CDFG began cooperation on the upper Sacramento River carcass survey to improve the precision of population estimates of winter Chinook salmon.

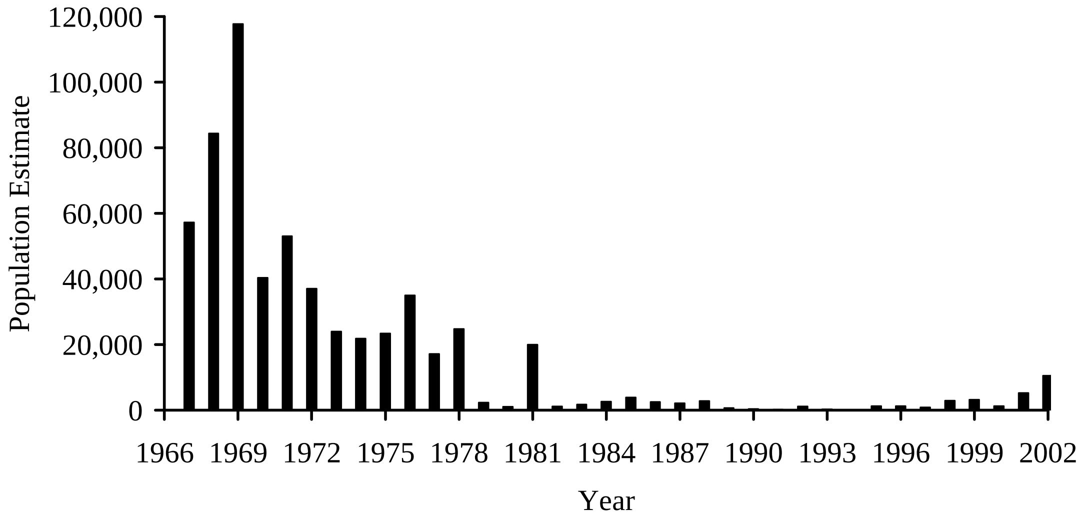

Figure 1. Population abundance estimates for Sacramento River winter Chinook salmon from 1967-2002.

Study Area

The 2002 winter Chinook carcass survey was conducted on the upper Sacramento River, California. The carcass survey was designed to encompass the primary spawning areas and entire spawning period of winter Chinook. The survey area covered 14 miles of the Sacramento River and was divided into two reaches (Figure 2); reach 1 extended from Keswick Dam (river mile [RM] 302) to the Cypress Street Bridge in Redding, California (RM 295); reach 2 extended from the Cypress Street Bridge to the Redding Water Treatment Plant (RM 288).

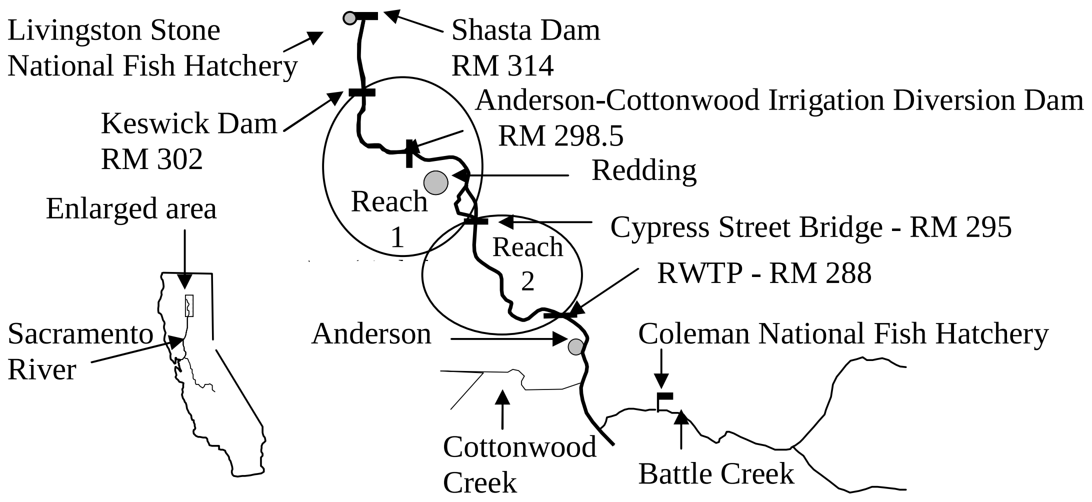

Figure 2. Upper Sacramento River and the 2002 winter Chinook salmon carcass survey sampling area. Reach 1 extends from Keswick Dam (river mile [RM] 302) down to Cypress Street Bridge (RM 295). Reach 2 extends from RM 295 down to the Redding Water Treatment Plant (RWTP, RM 288).

Methods

Carcass Recoveries

The carcass survey was conducted from 1 May through 27 August 2002.
To ensure the entire winter Chinook salmon spawning period was surveyed, additional reconnaissance surveys were conducted on 22 and 29 April and 12 and 19 September. The carcass survey was conducted in 3-day cycles with Reach 1 surveyed on the first day, Reach 2 surveyed on the second day, and no survey conducted on the third day. The survey was conducted with two boats, each having two observers. The boats surveyed from opposite shorelines to the middle of the river. Carcasses were collected using a 3 meter pole with an attached five-pronged gig. Data gathered included the following: date, location (reach and RM), carcass condition (fresh or non-fresh), gender, spawning status (spawned, partially spawned, unspawned, and unknown), fork length, and adipose fin status (absent, present, or unknown). Carcasses were considered to be fresh if they had two clear eyes or one clear eye and a firm body texture. Spawning status of females was based on an estimation of eggs remaining. Females were categorized as *spawned* (abdomen extremely flaccid or very few eggs remaining), *partially spawned* (moderately flaccid or a portion of eggs remained loose within the body cavity), *unspawned* (abdomen firm and swollen or many eggs remained), or as *unknown* (indeterminable spawning status, usually due to predation on the carcass). Males were always categorized as unknown because their spawning status could not be determined.

Adipose fin status was used to determine origin. An intact adipose fin (natural) was assumed to indicate natural origin. Carcasses missing an adipose fin (hatchery) were assumed to be of hatchery origin and likely contained a coded wire tag. The tag code provided the brood year and early life history information for hatchery fish.

We evaluated the winter Chinook supplementation program at Livingston Stone NFH by comparing spatial distribution, spawn timing, body size, age composition, gender composition, and spawning status of hatchery and natural winter Chinook. Carcasses with an adipose fin status of unknown were excluded from these analyses.

- Spatial Distributions of hatchery and natural winter Chinook were evaluated by comparing relative location of carcass recoveries. The frequency of carcass recoveries was plotted against river mile. Frequency distributions were visually compared and examined for substantive differences.

- Spawn Timing was evaluated by comparing temporal distributions of hatchery and natural carcasses recovered. The frequency of carcass recoveries was plotted against date for hatchery and natural winter Chinook. Frequency distributions were visually compared and examined for substantive differences.

- Body Size of hatchery and natural carcasses was compared using an ANOVA on fork length (mm) of carcass recoveries grouped by gender and age. Post-hoc comparisons were made using the Tukey highly significant difference test.

- Age Composition of hatchery winter Chinook salmon was evaluated using coded wire tag data. Age composition of natural winter Chinook salmon was determined using length frequency histograms. By looking for logical breaks in the frequency distributions, a cutoff value was determined to distinguish between grilse (age-2) and adults (≥ age-3) for both males and females. Age of hatchery and natural winter Chinook salmon was compared using Chi-square analysis.

- Gender Composition of hatchery and natural winter Chinook salmon was compared using Chi-square analysis.

- Spawning Status of hatchery and natural female winter Chinook was compared using Chi-square analysis.

A tissue sample was collected from the fin or operculum of carcasses that were not extremely decayed. On days in which the number of carcasses was expected to be less than 100, all suitable carcasses were tissue sampled. On days in which the number of carcasses was expected to exceed 100, tissue samples were collected from a sub-sample of carcasses. For example, on days when the survey crew anticipated collecting >100 carcasses a sub-sample ratio (e.g., 1:3) was chosen for the day, with one tissue sample collected for every three suitable carcasses.

A sub-sample of collected tissues was sent to the University of California-Davis genetics laboratory at Bodega Marine Laboratory. Tissue samples were analyzed at a suite of seven microsatellite genetic markers that were selected for their diagnostic power in distinguishing winter Chinook from other Chinook salmon populations (University of California – Davis Bodega Marine Laboratory 2001). A run assignment (winter and non-winter) was made based on a LOD score generated using the computer software WHICHRUN. Samples receiving a LOD score greater than zero were classified as a winter Chinook salmon. We hypothesized that nearly all Chinook salmon carcasses recovered during the peak winter Chinook spawning period (i.e., June and July) would be identified as winter Chinook and non-winter Chinook carcasses were more likely to be recovered during the early (April and May) and late (August and September) segments of the run. Therefore, we selected a random set of tissues stratified by sample date. All samples were analyzed from the early and late segments of the run as well as a random sub-sample of tissues from the peak spawning period.

Demographic Benefit of Hatchery Supplementation

The primary objective of the winter Chinook salmon supplementation program at Livingston Stone NFH is to increase abundance of the naturally spawning population. To evaluate this objective, we estimated replacement rates for naturally spawning salmon and applied these rates to the adults used as broodstock in the supplementation program. We then estimated the abundance of hatchery adult winter Chinook returning to the upper Sacramento River. Lastly, we compared these estimates of abundance with and without the supplementation program.

To conduct our comparison, we first estimated the number of adult winter Chinook salmon that would have been produced by the hatchery broodstock if they had not been removed from the naturally spawning population. We then calculated age-specific cohort replacement rates for the hatchery broodstock based on the typical age composition of winter Chinook salmon (Hallock and Fisher 1985) and recent winter Chinook salmon population estimates (Snider et al., 1999, 2000, 2001, 2002, and 2004 [in preparation]; Appendix A-1). We used population estimates based on the Peterson mark-recapture method because that estimator was available for every age class. We then estimated the number of female hatchery winter Chinook salmon that returned in 2002 by expanding coded wire tag recoveries of fresh female hatchery carcasses. The estimate of female hatchery returns was then expanded to include males based on the proportion of hatchery male and female winter Chinook salmon observed at the Keswick Dam Fish Trap (KDFT). This estimate was then expanded to account for non-fresh carcasses and the estimated number of carcasses not collected during the survey (Appendix A-2). Estimates of abundance with and without the supplementation program were then compared (Appendix A-3) to evaluate the change in winter Chinook abundance due to the supplementation program at the Livingston Stone National Fish Hatchery.

Results

Reconnaissance Surveys

No hatchery carcass was collected during the reconnaissance surveys. Nine natural carcasses were collected prior to the start of the carcass survey and all were sampled for tissues. Seven tissue samples were successfully analyzed with four (57.1%) identified as winter Chinook salmon and three (42.9%) as non-winter Chinook salmon. Six tissue samples were collected after the carcass survey. Of these, four were successfully analyzed and all four were identified as non-winter Chinook salmon (Appendix B).

Carcass Recoveries

A total of 4,946 carcasses was observed, including 4,738 natural, 202 hatchery, and 6 of unknown origin. Of the observed natural carcasses, 1,831 were examined for gender, fork length, and spawning condition.

Coded Wire Tag Recoveries

A coded wire tag was recovered and decoded from 141 of the 208 heads collected (Table 1, Appendix C). A tag was not detected in 60 of the heads and seven tags were initially found but lost during processing. One hundred forty of the tagged carcasses were from brood year 1998, 1999, and 2000 winter Chinook salmon reared at Livingston Stone NFH (Figure 3, Table 2, Appendix D). Eleven tags (code 0501021307) were recovered from progeny of brood year 1999 winter Chinook salmon captive broodstock. In addition, one tag (code 062659) was recovered from a brood year 1999 fall Chinook salmon reared at the Feather River Fish Hatchery. Data from this fish was excluded from all analyses and from Table 1.

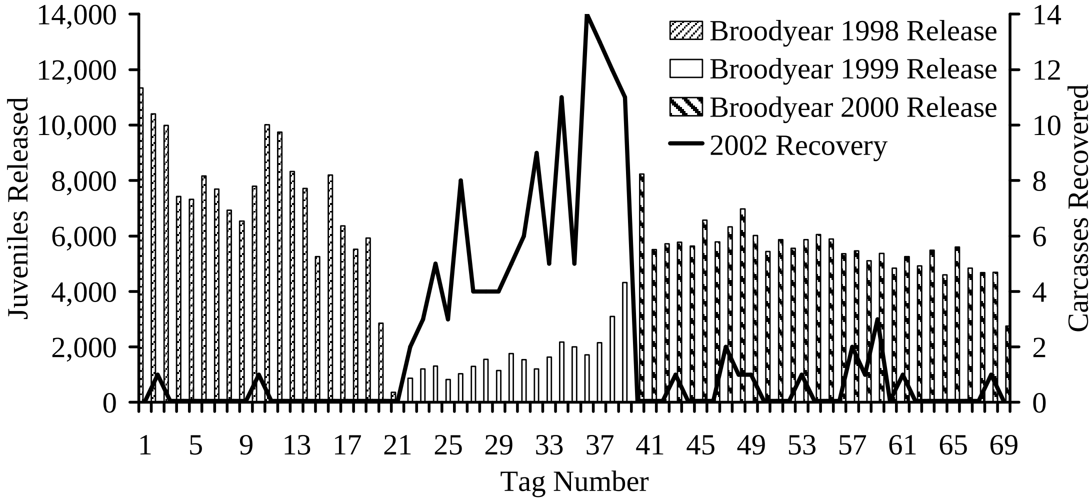

Figure 3. Number of juvenile winter Chinook salmon released and number of carcass recoveries by tag code and brood year in 2002 (each tag number corresponds to an individual tag code listed in Table 2).

Table 1. Number of coded wire tag (CWT) recoveries, tags not detected (NTD), and tags lost (Lost) during processing of heads from winter Chinook salmon collected during the 2002 upper Sacramento River carcass survey. See text for description of 'Carcass condition' and 'Adipose fin' status.

Gender	Carcass condition	Adipose Fin	CWT	NTD	Lost	Total
Female	Fresh	Hatchery	57	18	5	80
Female	Fresh	Unknown	1	1	0	2
Female	Non-fresh	Hatchery	60	32	0	92
Female	Non-fresh	Unknown	0	1	0	1
Female	Unknown	Hatchery	2	0	0	2
Male	Fresh	Hatchery	15	5	2	22
Male	Fresh	Unknown	0	1	0	1
Male	Non-fresh	Hatchery	4	1	0	5
Male	Non-fresh	Unknown	1	1	0	2
			140	60	7	207

Table 2. Coded wire tag (CWT) codes released, by brood year, from Livingston Stone National Fish Hatchery (tag numbers correspond to those reported in Figure 3). * CWT code 0501021307 was used for the progeny of captive broodstock held at the University of California-Davis Bodega Bay Marine Laboratory.

Broodyear 1998		Broodyear 1999		Broodyear 2000	
Tag Number	CWT Code	Tag Number	CWT Code	Tag Number	CWT Code
1	0501020811	22	0501021205	40	0501030107
2	0501020812	23	0501021206	41	0501030108
3	0501020813	24	0501021207	42	0501030109
4	0501020814	25	0501021208	43	0501030201
5	0501020815	26	0501021209	44	0501030202
6	0501020901	27	0501021210	45	0501030203
7	0501020902	28	0501021211	46	0501030204
8	0501020903	29	0501021212	47	0501030205
9	0501020904	30	0501021213	48	0501030206
10	0501020905	31	0501021214	49	0501030207
11	0501020906	32	0501021215	50	0501030208
12	0501020907	33	0501021301	51	0501030209
13	0501020908	34	0501021302	52	0501030301
14	0501020909	35	0501021303	53	0501030302
15	0501020910	36	0501021304	54	0501030303
16	0501020911	37	0501021305	55	0501030304
17	0501020912	38	0501021306	56	0501030305
18	0501020913	39	0501021307*	57	0501030306
19	0501020914			58	0501030307
20	0501020915			59	0501030308
21	0501021001			60	0501030309
				61	0501030401
				62	0501030402
				63	0501030403
				64	0501030404
				65	0501030405
				66	0501030406
				67	0501030407
				68	0501030408
				69	0501030409

Spatial Distribution
Both hatchery and natural carcasses were collected throughout the survey area, with the majority (86.1%) of carcasses found in Reach 1. More carcasses were found in Turtle Bay (RM 296.5) than any other location (Figure 4). The proportion of hatchery carcasses at each river mile was generally the same as natural carcasses. A notable exception was a larger proportion of hatchery carcasses were collected from river miles 299 and 300.

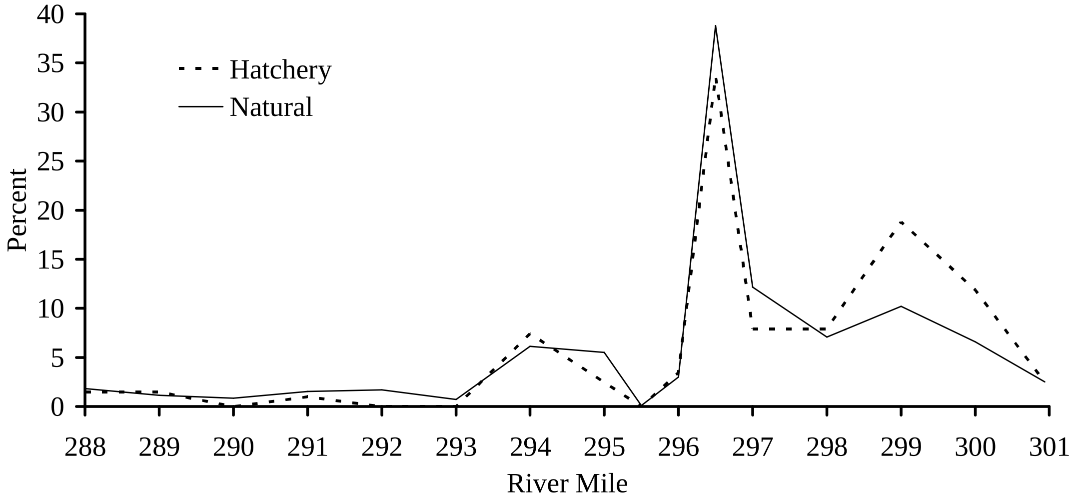

Figure 4. Percentage of carcasses with (hatchery) and without (natural) an adipose fin clip collected by river mile during the 2002 upper Sacramento River winter Chinook salmon carcass survey.

Spawn Timing
We recovered hatchery and natural winter Chinook salmon carcasses throughout the survey period. Hatchery and natural carcass recoveries followed a fairly normal (bell-shaped) temporal distribution with a peak in early July (Figure 5). A total of 202 hatchery carcasses were recovered: 38 in May, 86 in June, 77 in July, and 1 in August. Natural carcass recoveries (n = 4738) consisted of 531 in May, 1455 in June, 2547 in July, and 205 in August.

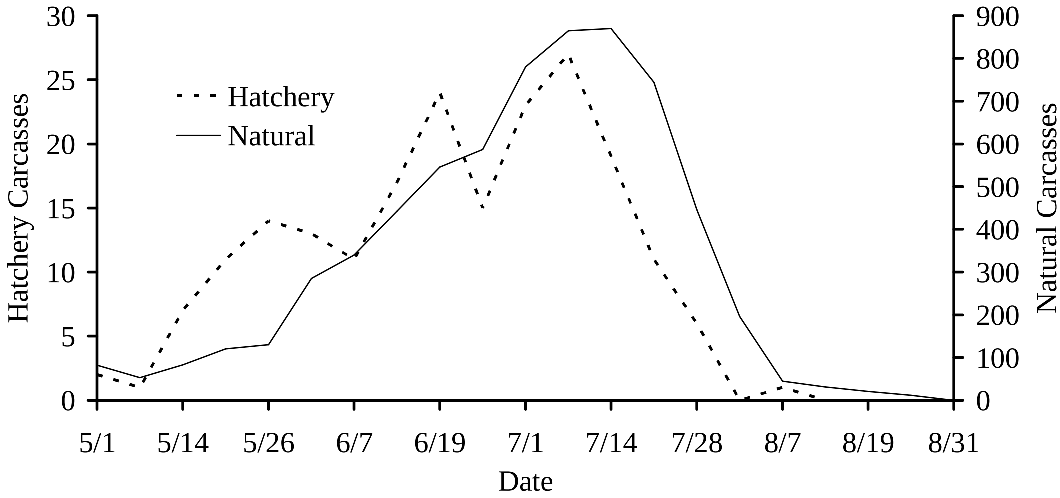

Figure 5. Date of collection for carcasses with (hatchery) and without (natural) an adipose fin clip recovered during the 2002 upper Sacramento River winter Chinook salmon carcass survey

Body Size

Only two hatchery grilse females were collected (500 and 730 mm). Adult hatchery females average 740 mm (range = 620-850 mm, SD = 41.9, Figure 6). Hatchery males averaged 543 mm (range = 470-650 mm, SD = 51.4) for grilse and 766 mm (range = 580-930 mm, SD = 103.1) for adults.

Using length-frequency analyses, Snider et al (2004, in preparation) determined that natural females <550 mm were grilse and >=550 mm were adults. Males <690 mm were categorized as grilse and >=690 mm as adults (Snider et al. 2004 [in preparation]). Natural females averaged 489 mm (range = 380-540, SD = 49.2) for grilse and 738 mm (range = 550-1090 mm; SD = 55.7) for adults. The average length of natural males averaged 581 mm (range = 460-680 mm; SD = 48.9) for grilse and 866 mm (range = 690-1100 mm; SD = 88.1) for adults.

Fork lengths of adult hatchery males were significantly smaller than adult natural males (ANOVA; df = 7, 1962; P < 0.001; Tukey test, P < 0.001). No difference in fork lengths was found for hatchery and natural grilse males (Tukey test, P = 0.457), grilse females (Tukey test, P = 0.136), and adult females (Tukey test, P = 1.000).

Age Composition

Hatchery carcasses consisted of 10.0% (n = 14) age two, 88.6% (n = 124) age three, and 1.4% (n = 2) age four, based on recovered coded wire tags. Hatchery females consisted of 1.7% (n = 2) age two, 97.5% (n = 117) age three, and 0.8% (n = 1) age four, whereas, hatchery male carcasses were 60.0% (n = 12) age two, 35.0% (n = 7) age three, and 5.0% (n = 1) age four.

Natural carcasses consisted of 5.9% (n = 108) grilse and 94.1% (n = 1723) adult, based on length-frequency histograms. Natural female carcasses were 0.9% (n = 13) grilse and 99.1% (n = 1360) adult, whereas, natural males consisted of 20.6% (n = 94) grilse and 79.4% (n = 363) adult. The gender could not be determined for one natural carcass (290 mm).

The proportion of hatchery males returning at age 2 (60.0%) was significantly greater than natural males (20.6%, Pearson Chi square; df = 1, $P < 0.001$). The proportion of hatchery females returning as grilse was not significantly different than natural females (Pearson Chi square; df = 1, $P = 0.448$).

Gender Composition
Hatchery carcasses consisted of 13.4% (n = 27) male and 86.6% (n = 175) female, whereas, natural carcasses consisted of 25.0% (n = 457) male and 75.0% (n = 1373) female. The proportion of hatchery fish returning as males was significantly less than natural fish (Pearson Chi square; df = 1, $P < 0.001$).

Spawning Status
Of the female hatchery carcasses, 96.6% (n = 169) were classified as spawned, 1.1% (n = 2) as partially spawned, and 2.3% (n = 4) as unspawned. Of the female natural carcasses, 98.2% (n = 1,348) were classified as spawned, 0.2% (n = 3) as partially spawned, 1.4% (n = 19) as unspawned, and 0.2% (n = 3) as unknown. The spawn status of hatchery and natural females was not statistically different (Pearson Chi square; df = 2, $P = 0.082$). Spawning status was not determined for males.

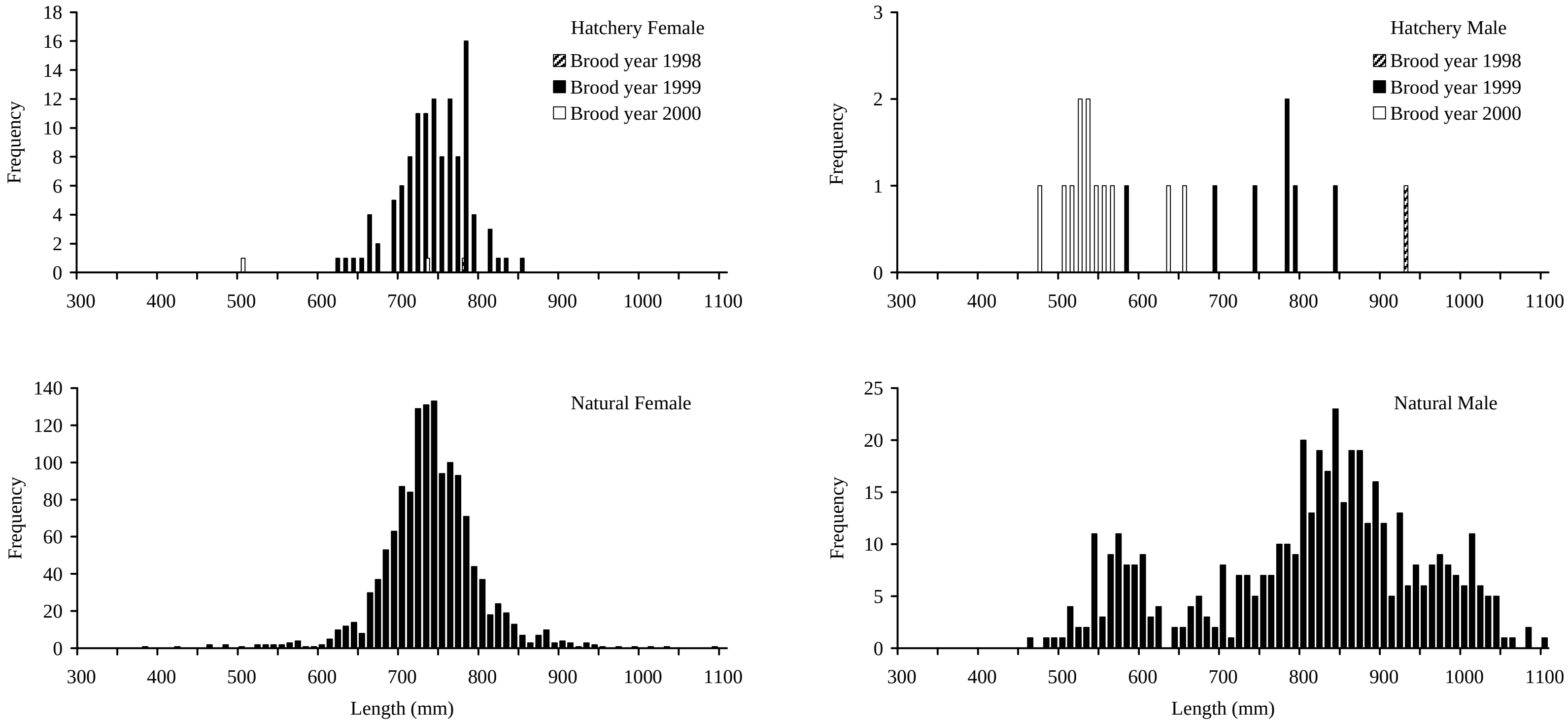

Figure 6. Length-frequency distribution of winter Chinook salmon collected during the 2002 upper Sacramento River winter Chinook salmon carcass survey. Data is presented for females without a clipped adipose fin (Natural Female), females with a clipped adipose fin (Hatchery Female), males without a clipped adipose fin (Natural Male), and males with a clipped adipose fin (Hatchery Male).

Genetic Analyses
Tissue samples were collected from 2,037 carcasses. Six hundred fifty tissue samples were sent to Bodega Marine Laboratory and 396 (60.9%) amplified at sufficient loci to make a run determination (Appendix B). Three hundred eighty four of the 396 (97.0%) tissue samples analyzed were identified as winter Chinook salmon, including: 96.0% (n = 121 of 126) in May, 99.1% (n = 112 of 113) in June, 99.1% (n = 114 of 115) in July, and 88.1% (n = 37 of 42) in August (Figure 7). The first genetically identified winter Chinook salmon was collected on 1 May 2002. The last genetically identified winter Chinook salmon was collected on 20 August 2002, after which only six carcasses suitable for tissue sampling were collected.

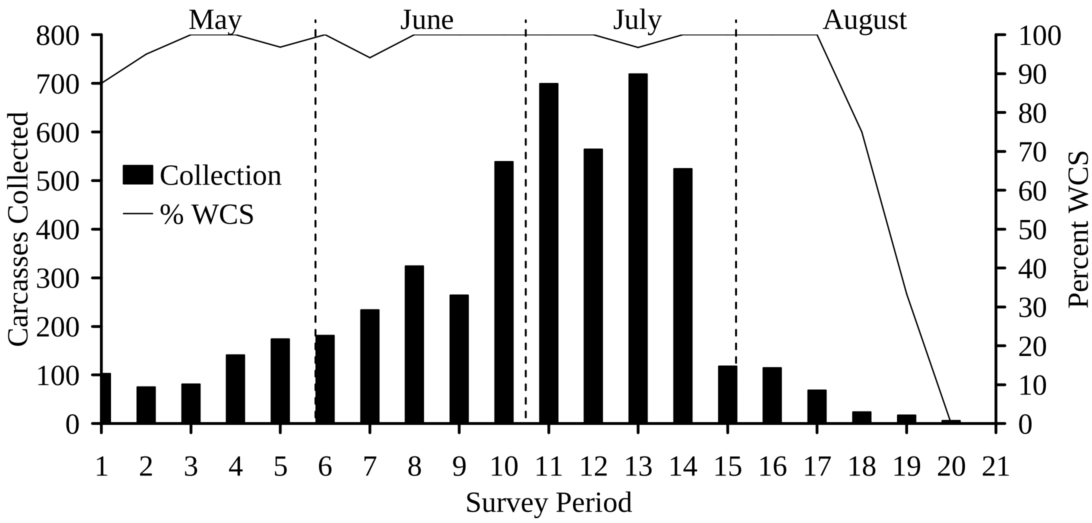

Figure 7. Total number of carcasses collected and percentage of tissue samples genetically identified (LOD > 0) as winter Chinook salmon (WCS) during the 2002 upper Sacramento River winter Chinook salmon carcass survey. One 'survey period' is equal to two surveys of each Reach 1 and Reach 2 (two survey cycles).

<u>Demographic Benefit of Hatchery Supplementation</u>

We estimate that 921 hatchery winter Chinook salmon returned in 2002 (Appendices A1-A3). Additionally, we estimate that the Chinook salmon adults used as hatchery broodstock at the Livingston Stone NFH in 1999, 2000, and 2001 would have resulted in 125 adult returns in 2002 had they been allowed to reproduce naturally. The results of our analyses indicate that the Service's winter Chinook salmon supplementation program increased escapement to the upper Sacramento River by 796 fish, equating to an increased demographic contribution of 637% by those fish used as hatchery broodstock.

Discussion

Reconnaissance Surveys

The low abundance of Chinook salmon carcasses observed and the low occurrence of genetically identified winter Chinook salmon during reconnaissance surveys, indicate that very few winter Chinook salmon are present outside the carcass survey period (May through August).

Carcass Recoveries

The Service's winter Chinook salmon supplementation program was moved from the Coleman NFH to the Livingston Stone NFH in 1998. The primary reason for moving the supplementation program to the mainstem of the Sacramento River was to improve homing of hatchery fish to spawning areas used by natural winter Chinook salmon. When the program was located at the Coleman NFH many hatchery winter Chinook salmon returned to Battle Creek. By incubating eggs and rearing juveniles at Livingston Stone NFH, it was believed that hatchery winter Chinook salmon would be much more likely to return to spawning areas in the mainstem Sacramento River. Recoveries of hatchery carcasses during the 2002 winter Chinook carcass survey shows that hatchery winter Chinook salmon from Livingston Stone NFH are imprinting and returning to spawning areas in the mainstem Sacramento River.

Coded Wire Tag Recoveries

All hatchery winter Chinook salmon recovered during the 2002 carcass survey were from Livingston Stone NFH brood years 1998, 1999, and 2000. Nearly all of the tag codes released from Livingston Stone NFH for brood years 1999 and 2000 were represented in the carcass recoveries. Each tag code represents an individual family group or a cluster of family groups, where a family group is defined as the progeny of an individual female and male mating. The recovery of many tag codes during the 2002 carcass survey, including all tag codes from brood year 1999 (age-3 adults), provides evidence that hatchery winter Chinook maintained the genetic diversity of their parent stock.

Spatial Distribution

The distribution of salmon carcasses was variable throughout the survey area, with areas of decreased velocity (pools) located below spawning areas typically showing a larger concentration of carcasses compared to areas of increased velocity (runs and riffles). We assume the spatial distributions of carcasses provide evidence of relative spawning locations for hatchery and natural winter Chinook. This assumption should be valid unless post-spawning behavioral difference exists between hatchery and natural winter Chinook.

Spatial distributions of hatchery and natural carcasses were remarkably similar throughout the survey area. The notable exception was the area above the Anderson-Cottonwood Irrigation District Diversion Dam (RM 299 – 301) where a substantially higher proportion of hatchery carcasses were observed. Hatchery winter Chinook salmon are incubated and reared at Livingston Stone NFH, located at the base of Shasta Dam (RM 314), and therefore they would be expected to imprint to waters coming out of Shasta Dam. Natural winter Chinook salmon imprint to waters within their natal spawning areas below Keswick Dam (RM 288 – 302). The increased incidence of hatchery carcasses within the uppermost region of the survey area suggests that a larger proportion of winter Chinook reared at the Livingston Stone NFH imprint and return to the uppermost reaches of available spawning habitats.

Spawn Timing

Hatchery carcasses were recovered in a similar temporal pattern as natural carcasses. We assume the temporal occurrence of carcass recoveries provides evidence of similar spawn timing for hatchery and natural winter Chinook salmon. This assumption should be valid unless differences exist in post-spawning longevity between hatchery and natural winter Chinook salmon.

Body Size

We determined that hatchery adult males returned at a smaller size than natural adult males. Possible explanations for this observed size difference include the following:

1) Hatchery fish may have difficulty transitioning to natural feeding strategies (Einum and Fleming 2001). If this were the case, however, it would be expected that body sizes of both hatchery males and females would differ from their natural counterparts.

2) Hatchery adults have been found to place more energy into development of gonadal tissue, as opposed to somatic tissue (Fleming and Gross 1992). If this were the case, it would also be expected that body sizes of both hatchery males and females would be different than their natural counterparts.

3) Hatchery fish are more likely to return to fresh water earlier in the spawning season (Chandler and Bjornn 1988; Einum and Fleming 2000; Mackey et al. 2001). Fish returning early would not benefit from the additional feeding time under ocean conditions. Again, it would be expected that body sizes of both hatchery males and females would be different than their natural counterparts.

4) Fish exhibiting faster growth are more likely to return at age 2 (Mullan et al. 1992; Silverstein et al. 1998; Larson et al. 2004). This occurs more often for males than females and in higher proportions for hatchery rather than natural fish (Larson et al. 2004). If this were to occur, a smaller proportion of fish predisposed for faster growth would be left in the hatchery population relative to the natural population.

Whether or not the observed size differences are merely statistical or are a reflection of actual biological differences will hopefully be established with the accumulation of more data from subsequent survey years.

Age Composition
Two year old hatchery and natural carcasses were almost exclusively male, "jacks." Two year old males occurred nearly three times as often in the hatchery male population (60.0%) compared to the natural male population (20.6%). Larson et al. (2004) found that increased precocial maturation of hatchery Chinook salmon is likely a result of accelerated growth in the hatchery environment.

Gender Composition
We observed a 1:6 hatchery and 1:3 natural male to female ratio during the carcass survey. This suggests the carcass survey may be biased against males, possibly more so for hatchery fish. The carcass survey is largely based on visual observation and may be biased against smaller fish (Zhou 2002). Hatchery adult males returned at a smaller size than natural adult males. Also, for hatchery and natural fish, males exhibit a different post-spawn behavior that may preclude them from observation on the carcass survey. This assumption is supported by observations of females guarding their redds, whereas male Chinook salmon are not typically observed near the vicinity of the redd after spawning.

Spawning Status
Low numbers of unspawned hatchery and natural female carcasses were observed suggesting similar spawning success. However, spawning success does not necessarily indicate that hatchery and natural fish are contributing equally to future generations. Several studies have shown that offspring from naturally reproducing hatchery fish, and matings between hatchery and natural fish, may have lower survival than offspring of natural fish (Leider et al. 1990; Waples 1991; Utter et al. 1993; Campton 1995; Reisenbichler and Rubin 1999). However, Ardren et al. (1999) found equal reproductive potential of hatchery and natural steelhead in the Hood River, Oregon. Rates of survival for progeny of naturally spawning hatchery winter Chinook salmon in the upper Sacramento River is not known.

Genetic Analyses
The high frequency of salmon identified as winter Chinook during the carcass survey, coupled with the low abundance of Chinook salmon observed during the reconnaissance surveys, suggests the winter Chinook salmon spawning period is being adequately surveyed in the Upper Sacramento River winter Chinook carcass survey.

<u>Demographic benefit of hatchery supplementation</u>

Hatchery fish represented 8.8% of the total winter Chinook salmon spawning population in 2002. Based on our calculations, it appears the winter Chinook salmon supplementation program succeeded in demographically enhancing the winter Chinook salmon population in 2002.

Conclusions

Adult escapement of winter Chinook salmon increased in 2002 as a result of the winter Chinook salmon supplementation program at Livingston Stone NFH. Recoveries of hatchery carcasses included several coded wire tag codes indicating that hatchery winter Chinook salmon contained several different family groups and likely maintained the genetic diversity of their parent stock. Both hatchery and natural winter Chinook were found throughout the survey area. However, hatchery fish were more likely to be recovered further upstream suggesting possible differences in spawning distribution. Hatchery winter Chinook salmon were recovered at the same times as natural fish which likely indicates similar spawn time. Adult hatchery males were smaller than adult natural males; however, no fork length differences existed among hatchery and natural grilse males, grilse females, and adult females. The proportion of hatchery males returning as grilse was greater than natural males but this difference was not observed for females. Compared to natural winter Chinook salmon, hatchery fish returned in smaller proportions as males, but considerably more females were recovered overall for both hatchery and natural fish. Hatchery and natural females appeared to have equal spawning success. Genetic analysis and other survey data indicate that we are adequately surveying the winter Chinook salmon spawning population in the upper Sacramento River.

Notes on apparent inconsistencies between the Sacramento River winter Chinook salmon carcass survey and fish trapping at the Keswick Dam

Winter Chinook salmon broodstock collection at Keswick Dam Fish Trap

Keswick Dam (RM 302) is a barrier to fish passage and represents the uppermost point of salmonid migration in the Sacramento River. A fish trap at Keswick Dam is used to capture broodstock for the winter Chinook salmon supplementation program. Broodstock collection activities for winter Chinook salmon are conducted according to an annual Adult Collection Plan that identifies monthly broodstock collection targets for January through July. Winter Chinook salmon in excess of broodstock needs (or in excess of monthly targets) and non-winter Chinook salmon are returned to the Sacramento River either at Bonnyview Road boat ramp (RM 292) or Caldwell Park boat ramp (RM 298), depending on flow. Fish are floy tagged for identification before they are released back into the river.

Comparison of adipose fin clip rates

During 2002, hatchery Chinook salmon (n = 75) comprised 29.9% of the total Chinook salmon (n = 251) trapped at the Keswick Dam Fish Trap (KDFT), whereas hatchery carcasses (n = 107) represented only 5.3% of the total fresh carcasses (n = 2020) recovered on the carcass survey. This discrepancy may result if hatchery winter Chinook salmon have a tendency to return to the uppermost reaches of the Sacramento River. This hypothesis is supported by the large proportion of hatchery winter Chinook salmon captured at the KDFT. This hypothesis is also supported by our 2002 carcass survey where hatchery Chinook salmon were found at a greater rate than natural Chinook salmon within the two miles immediately below Keswick Dam.

Recoveries of floy tagged fish released from the Keswick Dam Fish Trap

During 2002, a total of 100 genetically identified winter Chinook salmon were captured at the KDFT, floy tagged, and then released back into the Sacramento River. Four of these tagged fish were subsequently recovered[1] on the carcass survey (Table 3), for a recovery rate of 4.0%. This recovery rate for fish released from the KDFT compares to a recovery rate of approximately 59% for Chinook salmon that were tagged as part of the carcass survey mark-recapture estimate (Snider et al. 2004 [in preparation]). During the carcass survey, 3,619 adult carcasses were tagged, of which 2,116 were subsequently recovered giving a recovery rate of 58.4%. Considering only fresh carcasses, the recovery rate was similar with 1,136 recoveries out of a total of 1,915 fresh carcasses tagged, for a recovery rate of 59.3%.

Several hypotheses have been proposed to explain the discrepancy between recovery rates for floy tagged fish released from the KDFT and carcasses tagged as part of the

[1] Two floy tagged Chinook salmon from the KDFT were released and subsequently recaptured at Keswick Dam, both fish were re-released back into the Sacramento River.

mark-recapture survey. These include: 1) live fish released from the KDFT may shed their floy tags during spawning activities, or post-spawning as their body condition deteriorates, 2) the fish released from the KDFT may spawn in the deep water areas immediately below Keswick Dam where their carcasses may be unlikely to be recovered due to the river's morphology, or 3) the fish released from the KDFT may fall back below the survey areas due to the stress of being captured, transported, tissue sampled, tagged, and released.

Table 3. Date Chinook salmon were captured at the Keswick Dam Fish Trap and floy tagged, location (name of boat ramp and river mile [RM]) and date they were released back into the Sacramento River, and location and date floy tagged carcass were recovered during the 2002 upper Sacramento River winter Chinook salmon carcass survey.

	Floy Tag Number			
	OR-238	R-11910	R-04019	R-04021
Date floy tagged	20 February 2002	17 April 2002	19 June 2002	19 June 2002
Release location	Bonneyview	Caldwell	Caldwell	Caldwell
	RM 292	RM 298	RM 298	RM 298
Release date	27 February 2002	17 April 2002	19 June 2002	19 June 2002
Recovery location	RM 298	RM 299	RM 299	RM 296.5
Recovery date	22 May 2002	19 May 2002	3 July 2002	21 June 2002

Recommendations

In order to address these apparent inconsistencies between the KDFT and the carcass survey, we recommend that additional research be conducted to assess the abundance and composition of that segment of the winter Chinook salmon population that returns in the uppermost section of the Sacramento River, between the Anderson-Cottonwood Irrigation District Diversion Dam and the Keswick Dam. We believe that the fish ladders at the Anderson-Cottonwood Irrigation District Diversion Dam may provide a valuable monitoring location for winter Chinook salmon beginning in April when the flashboards are installed. Additional research using radio telemetry would allow us to document the movements of winter Chinook salmon in the upper Sacramento River. These studies have the potential to provide valuable insights into possible biases associated with winter Chinook salmon population estimates in the upper Sacramento River based on the mark-recapture methods.

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Appendix A. Analysis of demographic benefit resulting from the winter Chinook salmon supplementation program at Livingston Stone NFH based on the 2002 upper Sacramento River winter Chinook salmon carcass survey. Analysis includes estimation of winter Chinook salmon escapement in absence of a supplementation program (Appendix A-1), estimation of hatchery winter Chinook salmon escapement with the existing supplementation program (Appendix A-2), and a comparison of these two estimates (Appendix A-3).

Appendix A-1. Estimation of the 2002 winter Chinook salmon escapement in absence of a supplementation program.

Methods and Equations

We estimated the number of natural fish that would have returned without supplementation from Livingston Stone NFH. More specifically, we estimated the number of natural offspring that would have been produced by fish retained for hatchery broodstock had these fish been allowed to spawn naturally. We first calculated the abundance of each age class (n_A):

$$n_A = P_{Total} \times A_P \tag{1}$$

where,

P_{Total} = total adult winter Chinook salmon population (as estimated by the Peterson method) and

Note: The Jolly-Seber method is generally considered the more accurate estimator of winter Chinook escapement; however, estimates using the Jolly-Seber method have only been available since 2000. Therefore, we used the escapement estimate based on the Peterson method because it is available for all survey years and provides consistent methodology for estimating population abundance trends.

A_P = proportion of each age class present in the overall population (assumed: 0.25 age 2, 0.67 age 3, and 0.08 age 4 [Hallock and Fisher 1985]).

Replacement rates for each age class (r_A) were then estimated:

$$r_A = n_A / P_{BY} \tag{2}$$

where,

P_{BY} = total winter Chinook salmon escapement estimate for the corresponding brood year. For example, for fish returning in 2002 the corresponding brood year is: 2000 for age 2, 1999 for age 3, and 1998 for age 4.

For each age, we estimated the expected number of adult returns ($n_{Natural}$) that would have resulted had the adults retained for broodstock in previous years been allowed to spawn naturally:

$$n_{Natural} = r_A \times n_B \tag{3}$$

where,

n_B = number of adults retained as hatchery broodstock for the corresponding brood year. For example, for fish returning in 2002 the corresponding brood year is: 2000 for age 2, 1999 for age 3, and 1998 for age 4.

Summing across years, we estimated the total expected number of natural adult returns ($N_{Natural}$) that would have resulted had the adults retained for broodstock in previous years been allowed to spawn naturally:

$$N_{Natural} = \Sigma\,(n_{Natural}). \qquad (4)$$

<u>Data and Calculations</u>

	P_{Total}	=	**10,530**	**=**	2002	Total escapement
2 year old	P_{BY}	=	**6,670**	**=**	2000	Total escapement
3 year old	P_{BY}	=	**2,262**	**=**	1999	Total escapement
4 year old	P_{BY}	=	**5,501**	**=**	1998	Total escapement
2 year old	n_B	=	**85**	**=**	2000	Adult broodstock
3 year old	n_B	=	**24**	**=**	1999	Adult broodstock
4 year old	n_B	=	**106**	**=**	1998	Adult broodstock

Age Composition

P_{Total}	×	A_P	=	n_A		
10,530	×	0.25	=	**2,632.5000**	=	2002 , 2 year old escapement
10,530	×	0.67	=	**7,055.1000**	=	2002 , 3 year old escapement
10,530	×	0.08	=	**842.4000**	=	2002 , 4 year old escapement

Contribution Rate

n_A	/	P_{BY}	=	r_A		
2,632.5000	/	6670	=	**0.3947**	=	2000 Contribution rate
7,055.1000	/	2262	=	**3.1190**	=	1999 Contribution rate
842.4000	/	5501	=	**0.1531**	=	1998 Contribution rate

Recruitment of Adults

r_A	×	n_B	=	$n_{Natural}$		
0.3947	×	85	=	**33.5476**	=	2000 Adult Returns
3.1190	×	24	=	**74.8552**	=	1999 Adult Returns
0.1531	×	106	=	**16.2324**	=	1998 Adult Returns
				124.6352	**=**	$\mathbf{N_{Natural}}$

Appendix A-2. Estimated escapement of hatchery winter Chinook salmon in the upper Sacramento River for 2002.

Methods and Equations

We estimated the number of hatchery winter Chinook salmon that returned to the spawning grounds in 2002. Estimates of hatchery escapement were based on fresh female carcasses to address biases associated with the carcass survey; these include: 1) the ability to determine an adipose fin clip is likely more accurate for fresh carcasses and 2) the carcass survey is likely biased against males. We first estimated the number of fresh adult females in the upper Sacramento River and then expanded this estimate to include male, non-fresh, and unobserved carcasses. Our estimate was expanded to include males based on the proportion of male to female hatchery winter Chinook salmon observed at the Keswick Dam Fish Trap. We expanded our estimate to include non-fresh carcasses based on the proportion of fresh to non-fresh carcasses observed during the carcass survey. Lastly, we expanded our estimate to include carcasses not observed based on the proportion of carcasses observed during the carcass survey to the total estimated escapement of winter Chinook salmon for 2002.

To estimate the number of female hatchery winter Chinook salmon, we began by apportioning fresh female coded wire tag recoveries, by code, among the total recoveries of fresh female carcasses with a coded wire tag (CWT_P):

$$CWT_P = f_{CWT} / F_{CWT} \tag{5}$$

where,

f_{CWT} = number of coded wire tag recoveries from fresh female carcasses by tag code and

F_{CWT} = total coded wire tag recoveries from fresh female carcasses.

A tag was never detected in some adipose fin clipped carcasses (F_{NTD}). Additionally, coded wire tags were initially detected in some adipose fin clipped carcasses but subsequently lost during processing (F_{Lost}). We accounted for all adipose fin clipped carcasses by tag code ($f_{Clipped}$):

$$f_{Clipped} = (P_{CWT} \times F_{NTD}) + (P_{CWT} \times F_{Lost}) + f_{CWT} \tag{6}$$

For each tag code, we then expanded $f_{Clipped}$ to include fresh female hatchery adult carcasses without an adipose fin clip (f_{Fresh}) based on the proportion of juveniles with an adequate clip to the total number of juveniles observed during prerelease sampling:

$$f_{Fresh} = f_{Clipped} / (J_{Clipped} \times J_{Total}) \tag{7}$$

where,

$J_{Clipped}$ = the number of juveniles released with an adipose fin clip by tag code and

J_{Total} = the total number of juveniles released by tag code.

Next, we then summed f_{Fresh} and expanded it to include fresh hatchery male carcasses (H_{Fresh}) based on the proportion of hatchery females to males observed in the Keswick Dam Fish Trap:

$$H_{Fresh} = F_{Fresh} / (F_{KDFT} / H_{KDFT}) \quad (8)$$

where,

$F_{Fresh} = \Sigma\ (f_{Fresh})$,

F_{KDFT} = the number of adipose fin clipped female winter Chinook salmon captured in the Keswick Dam Fish Trap, and

H_{KDFT} = the total number of adipose fin clipped winter Chinook salmon captured in the Keswick Dam Fish Trap.

We can then expand H_{Fresh} to include non-fresh hatchery carcasses ($H_{Observed}$) based on the proportion of fresh to non-fresh carcasses observed during the carcass survey:

$$H_{Observed} = H_{Fresh} / (C_{Fresh} / C_{Observed}) \quad (9)$$

where,

C_{Fresh} = the number of fresh hatchery and natural carcasses observed during the carcass survey and

$C_{Observed}$ = the total number of hatchery and natural carcasses observed during the carcass survey.

Lastly, we can then expand $H_{Observed}$ to include hatchery carcasses not observed (H_{Total}) based on the proportion of total carcasses observed during the carcass survey to the total estimated escapement of winter Chinook salmon:

$$H_{Total} = H_{Observed} / (C_{Observed} / P_{Total}) \quad (10)$$

where,

P_{Total} = the total escapement of hatchery and natural carcasses estimated by the Peterson method.

Data and Calculations

F_{NTD}	=	18 =	Number of tags not detected during processing
F_{Lost}	=	5 =	Number of tags lost during processing
F_{KDFT}	=	34 =	Total hatchery females collected at Keswick Dam
H_{KDFT}	=	74 =	Total hatchery fish collected at Keswick Dam
C_{Fresh}	=	2,020 =	Fresh carcasses observed during the carcass survey
$C_{Observed}$	=	4,946 =	Total carcasses observed during the carcass survey
P_{Total}	=	10,530 =	Total winter Chinook salmon escapement

	f_{CWT} by BY		Prerelease Tag Retention Data			
CWT Code	1998	1999	C/T	C/NT	NC/T	NC/NT
0501020812	1		196	1	2	1
0501021205		2	198	1	1	0
0501021206		2	196	3	1	0
0501021207		2	196	3	1	0
0501021208		1	197	3	0	0
0501021209		4	194	4	2	0
0501021210		1	193	4	3	0
0501021211		1	199	1	0	0
0501021212		3	200	0	0	0
0501021213		2	197	3	0	0
0501021214		4	200	0	0	0
0501021215		6	199	1	0	0
0501021301		3	193	7	0	0
0501021302		4	194	6	0	0
0501021303		2	199	0	1	0
0501021304		7	200	0	0	0
0501021305		3	198	2	0	0
0501021306		5	197	3	0	0
0501021307		5	196	3	1	0
F_{CWT} =	58					

For Tag Retention Data:

C = fish with an adipose fin clip
NC = fish with no adipose fin clip
T = fish with a coded wire tag
NT = fish with no coded wire tag

Female adipose fin clipped carcasses observed

CWT Code	f_{CWT}		F_{CWT}		CWT_P		CWT_P		F_{NTD}		CWT_P		F_{Lost}		f_{CWT}		$f_{Clipped}$
0501020812	1	/	58	=	**0.0172**	, (	0.0172	×	18	) + (	0.0172	×	5	) +	1	=	**1.3966**
0501021205	2	/	58	=	**0.0345**	, (	0.0345	×	18	) + (	0.0345	×	5	) +	2	=	**2.7931**
0501021206	2	/	58	=	**0.0345**	, (	0.0345	×	18	) + (	0.0345	×	5	) +	2	=	**2.7931**
0501021207	2	/	58	=	**0.0345**	, (	0.0345	×	18	) + (	0.0345	×	5	) +	2	=	**2.7931**
0501021208	1	/	58	=	**0.0172**	, (	0.0172	×	18	) + (	0.0172	×	5	) +	1	=	**1.3966**
0501021209	4	/	58	=	**0.0690**	, (	0.0690	×	18	) + (	0.0690	×	5	) +	4	=	**5.5862**
0501021210	1	/	58	=	**0.0172**	, (	0.0172	×	18	) + (	0.0172	×	5	) +	1	=	**1.3966**
0501021211	1	/	58	=	**0.0172**	, (	0.0172	×	18	) + (	0.0172	×	5	) +	1	=	**1.3966**
0501021212	3	/	58	=	**0.0517**	, (	0.0517	×	18	) + (	0.0517	×	5	) +	3	=	**4.1897**
0501021213	2	/	58	=	**0.0345**	, (	0.0345	×	18	) + (	0.0345	×	5	) +	2	=	**2.7931**
0501021214	4	/	58	=	**0.0690**	, (	0.0690	×	18	) + (	0.0690	×	5	) +	4	=	**5.5862**
0501021215	6	/	58	=	**0.1034**	, (	0.1034	×	18	) + (	0.1034	×	5	) +	6	=	**8.3793**
0501021301	3	/	58	=	**0.0517**	, (	0.0517	×	18	) + (	0.0517	×	5	) +	3	=	**4.1897**
0501021302	4	/	58	=	**0.0690**	, (	0.0690	×	18	) + (	0.0690	×	5	) +	4	=	**5.5862**
0501021303	2	/	58	=	**0.0345**	, (	0.0345	×	18	) + (	0.0345	×	5	) +	2	=	**2.7931**
0501021304	7	/	58	=	**0.1207**	, (	0.1207	×	18	) + (	0.1207	×	5	) +	7	=	**9.7759**
0501021305	3	/	58	=	**0.0517**	, (	0.0517	×	18	) + (	0.0517	×	5	) +	3	=	**4.1897**
0501021306	5	/	58	=	**0.0862**	, (	0.0862	×	18	) + (	0.0862	×	5	) +	5	=	**6.9828**
0501021307	5	/	58	=	**0.0862**	, (	0.0862	×	18	) + (	0.0862	×	5	) +	5	=	**6.9828**
																	81.0000

Expansion to include non-adipose fin clipped females

CWT Code	$f_{Clipped}$		$J_{Clipped}$		J_{Total}			f_{Fresh}
0501020812	1.3966	/ (	197	/	200	)	=	**1.4178**
0501021205	2.7931	/ (	199	/	200	)	=	**2.8071**
0501021206	2.7931	/ (	199	/	200	)	=	**2.8071**
0501021207	2.7931	/ (	199	/	200	)	=	**2.8071**
0501021208	1.3966	/ (	200	/	200	)	=	**1.3966**
0501021209	5.5862	/ (	198	/	200	)	=	**5.6426**
0501021210	1.3966	/ (	197	/	200	)	=	**1.4178**
0501021211	1.3966	/ (	200	/	200	)	=	**1.3966**
0501021212	4.1897	/ (	200	/	200	)	=	**4.1897**
0501021213	2.7931	/ (	200	/	200	)	=	**2.7931**
0501021214	5.5862	/ (	200	/	200	)	=	**5.5862**
0501021215	8.3793	/ (	200	/	200	)	=	**8.3793**
0501021301	4.1897	/ (	200	/	200	)	=	**4.1897**
0501021302	5.5862	/ (	200	/	200	)	=	**5.5862**
0501021303	2.7931	/ (	199	/	200	)	=	**2.8071**
0501021304	9.7759	/ (	200	/	200	)	=	**9.7759**
0501021305	4.1897	/ (	200	/	200	)	=	**4.1897**
0501021306	6.9828	/ (	200	/	200	)	=	**6.9828**
0501021307	6.9828	/ (	199	/	200	)	=	**7.0178**
						H_{Fresh}	=	**81.1902**

Expansion to include fresh males

$\mathbf{H_{Fresh}}$		F_{Fresh}		F_{KDFT}		H_{KDFT}	
176.7081	=	81.1902	/ (	34	/	74	)

Expansion to include non-fresh hatchery carcasses

$\mathbf{H_{Observed}}$		H_{Fresh}		C_{Fresh}		$C_{Observed}$	
432.6723	=	176.7081	/ (	2020	/	4946	)

Expansion to include carcasses not observed

$\mathbf{H_{Total}}$		$H_{Observed}$		$C_{Observed}$		P_{Total}	
921.1564	=	432.6723	/ (	4946	/	10,530	)

Appendix A-3. Comparison of estimated escapement with and without the supplementation program.

Methods and Equations

To determine the number of hatchery winter Chinook salmon returning at each age (H_{Age}), we multiplied the estimated total hatchery adults (H_{Total}) by the expected proportions returning at each age (Hallock and Fisher 1985):

$$H_{Age} = H_{Total} \times A_P. \tag{14}$$

We can then compare our estimated returns in absence of the supplementation program to returns with the existing program.

Data and Calculations

Age (yr)	$\mathbf{H_{Age}}$		H_{Total}		A_P
2 (from year 2000 adults)	**230.2891**	=	921.1564	×	0.25
3 (from year 1999 adults)	**617.1748**	=	921.1564	×	0.67
4 (from year 1998 adults)	**73.6925**	=	921.1564	×	0.08

Comparison of Appendix A-1 and A-2

Age (year)	Natural	Hatchery	Percent Increase
2	34	230	576
3	75	617	723
4	16	74	363
Total	**125**	**921**	**637**

An estimated 125 fish would have returned without the supplementation program (Appendix A-1), however, an estimated 921 hatchery fish returned in 2002. Offspring of the winter Chinook salmon adults used as broodstock for propagation at Livingston Stone NFH returned at a rate 637% greater than the estimated escapement if these adults had been allowed to spawn naturally.

Appendix B. Genetic results of fin tissues collected from Chinook salmon carcasses during the 2002 upper Sacramento River winter Chinook salmon carcass survey. Data presented includes sample collection date, sample number assigned by the Service, LOD score determined by the Bodega Bay Marine Laboratory (University of California-Davis), and the genetic call (LOD > 0 for winter).

Collection Date	Sample Number	LOD Score	GeneticCall
4/22/2002	02-2001	-7.36	Non-Winter
4/22/2002	02-2002	10.03	Winter
4/22/2002	02-2003	7.48	Winter
4/29/2002	02-2007	7.64	Winter
4/29/2002	02-2008	-3.12	Non-Winter
4/29/2002	02-2010	-5.99	Non-Winter
4/29/2002	02-2012	7.16	Winter
5/1/2002	02-2101	6.52	Winter
5/1/2002	02-2102	2.04	Winter
5/1/2002	02-2103	8.96	Winter
5/1/2002	02-2107	-5.99	Non-Winter
5/2/2002	02-2108	2.37	Winter
5/2/2002	02-2109	4.78	Winter
5/2/2002	02-2110	-7.32	Non-Winter
5/2/2002	02-2111	-3.40	Non-Winter
5/4/2002	02-2112	9.17	Winter
5/4/2002	02-2113	7.42	Winter
5/4/2002	02-2114	7.41	Winter
5/4/2002	02-2118	10.47	Winter
5/4/2002	02-2119	9.37	Winter
5/4/2002	02-2121	9.64	Winter
5/4/2002	02-2122	8.90	Winter
5/4/2002	02-5405	6.11	Winter
5/5/2002	02-2126	6.35	Winter
5/5/2002	02-2129	4.85	Winter
5/7/2002	02-2132	3.49	Winter
5/7/2002	02-2135	3.41	Winter
5/7/2002	02-2136	4.38	Winter
5/7/2002	02-2137	7.01	Winter
5/7/2002	02-2139	2.45	Winter
5/7/2002	02-5407	5.58	Winter
5/10/2002	02-2142	6.58	Winter
5/10/2002	02-2144	5.10	Winter
5/10/2002	02-2149	7.65	Winter
5/10/2002	02-2151	9.33	Winter
5/10/2002	02-2152	7.10	Winter

Collection Date	Sample Number	LOD Score	GeneticCall
5/10/2002	02-2153	9.43	Winter
5/10/2002	02-2154	9.71	Winter
5/11/2002	02-2158	6.92	Winter
5/13/2002	02-2162	8.68	Winter
5/13/2002	02-2164	8.18	Winter
5/13/2002	02-2165	8.26	Winter
5/13/2002	02-2167	9.03	Winter
5/13/2002	02-2169	3.67	Winter
5/13/2002	02-2173	1.89	Winter
5/13/2002	02-2175	5.03	Winter
5/13/2002	02-2179	3.15	Winter
5/13/2002	02-5413	9.02	Winter
5/13/2002	02-5414	7.85	Winter
5/13/2002	02-5415	-5.03	Non-Winter
5/13/2002	02-5416	6.20	Winter
5/14/2002	02-2183	5.45	Winter
5/16/2002	02-2004	6.19	Winter
5/16/2002	02-2006	4.75	Winter
5/16/2002	02-2188	6.39	Winter
5/16/2002	02-2189	6.56	Winter
5/16/2002	02-2190	6.50	Winter
5/16/2002	02-2192	3.04	Winter
5/16/2002	02-2194	4.96	Winter
5/16/2002	02-2195	4.52	Winter
5/16/2002	02-2197	8.68	Winter
5/16/2002	02-2199	3.00	Winter
5/16/2002	02-2200	2.75	Winter
5/16/2002	02-5421	9.58	Winter
5/16/2002	02-5422	9.63	Winter
5/17/2002	02-2016	6.96	Winter
5/19/2002	02-2027	5.97	Winter
5/19/2002	02-2029	10.93	Winter
5/19/2002	02-2030	11.18	Winter
5/19/2002	02-2032	6.08	Winter
5/19/2002	02-2035	7.12	Winter
5/20/2002	02-2040	6.44	Winter
5/20/2002	02-2041	4.53	Winter
5/22/2002	02-2044	9.84	Winter
5/22/2002	02-2045	5.24	Winter
5/22/2002	02-2049	2.74	Winter
5/22/2002	02-2050	3.85	Winter
5/22/2002	02-2051	9.50	Winter

Collection Date	Sample Number	LOD Score	GeneticCall
5/22/2002	02-2052	9.61	Winter
5/22/2002	02-2053	5.78	Winter
5/22/2002	02-2055	8.18	Winter
5/22/2002	02-2056	5.96	Winter
5/22/2002	02-2058	8.80	Winter
5/22/2002	02-2063	6.12	Winter
5/22/2002	02-2064	9.34	Winter
5/22/2002	02-2070	5.54	Winter
5/22/2002	02-2072	8.28	Winter
5/22/2002	02-2074	7.09	Winter
5/22/2002	02-2075	5.42	Winter
5/22/2002	02-2081	9.26	Winter
5/22/2002	02-2085	9.27	Winter
5/22/2002	02-5451	4.33	Winter
5/22/2002	02-5453	5.35	Winter
5/23/2002	02-2087	10.22	Winter
5/23/2002	02-2088	10.93	Winter
5/25/2002	02-2095	5.69	Winter
5/25/2002	02-2098	1.47	Winter
5/25/2002	02-5511	0.44	Winter
5/25/2002	02-5515	1.88	Winter
5/25/2002	02-5518	2.38	Winter
5/25/2002	02-5520	1.17	Winter
5/25/2002	02-5521	3.91	Winter
5/26/2002	02-5455	3.09	Winter
5/28/2002	02-2202	9.13	Winter
5/28/2002	02-2204	5.44	Winter
5/28/2002	02-2205	4.06	Winter
5/28/2002	02-2206	3.47	Winter
5/28/2002	02-2212	4.52	Winter
5/28/2002	02-2219	4.65	Winter
5/28/2002	02-2232	8.58	Winter
5/28/2002	02-5458	3.73	Winter
5/28/2002	02-5462	3.86	Winter
5/28/2002	02-5463	1.95	Winter
5/28/2002	02-5465	1.78	Winter
5/28/2002	02-5469	3.12	Winter
5/28/2002	02-5474	1.96	Winter
5/29/2002	02-2247	2.59	Winter
5/29/2002	02-2250	8.01	Winter
5/29/2002	02-2254	5.72	Winter
5/29/2002	02-2256	8.90	Winter

Collection Date	Sample Number	LOD Score	GeneticCall
5/29/2002	02-2259	7.77	Winter
5/29/2002	02-2260	6.32	Winter
5/31/2002	02-2265	2.79	Winter
5/31/2002	02-2266	7.39	Winter
5/31/2002	02-2267	7.09	Winter
5/31/2002	02-2268	8.58	Winter
5/31/2002	02-2270	5.31	Winter
5/31/2002	02-2273	10.47	Winter
5/31/2002	02-2281	2.06	Winter
5/31/2002	02-2282	7.21	Winter
5/31/2002	02-5481	4.35	Winter
5/31/2002	02-5482	2.80	Winter
5/31/2002	02-5483	-1.53	Non-Winter
6/1/2002	02-2287	3.15	Winter
6/3/2002	02-2300	1.77	Winter
6/3/2002	02-2303	1.45	Winter
6/3/2002	02-2311	5.43	Winter
6/3/2002	02-2314	7.62	Winter
6/3/2002	02-2318	7.96	Winter
6/6/2002	02-2338	10.91	Winter
6/6/2002	02-2351	8.29	Winter
6/6/2002	02-5526	2.77	Winter
6/6/2002	02-5527	4.46	Winter
6/6/2002	02-5537	4.68	Winter
6/6/2002	02-5541	2.67	Winter
6/9/2002	02-2365	4.61	Winter
6/9/2002	02-2368	5.67	Winter
6/9/2002	02-2370	6.61	Winter
6/9/2002	02-2380	3.88	Winter
6/9/2002	02-2381	8.19	Winter
6/9/2002	02-2382	6.69	Winter
6/9/2002	02-2387	4.45	Winter
6/9/2002	02-5552	2.52	Winter
6/9/2002	02-5556	2.80	Winter
6/9/2002	02-5557	-0.85	Non-Winter
6/12/2002	02-2397	5.43	Winter
6/12/2002	02-2398	5.72	Winter
6/12/2002	02-2409	2.98	Winter
6/12/2002	02-2415	3.04	Winter
6/12/2002	02-2419	7.36	Winter
6/12/2002	02-5562	2.70	Winter
6/12/2002	02-5567	1.85	Winter

Collection Date	Sample Number	LOD Score	GeneticCall
6/13/2002	02-2432	9.10	Winter
6/13/2002	02-2442	9.80	Winter
6/13/2002	02-5577	1.85	Winter
6/15/2002	02-2453	1.86	Winter
6/15/2002	02-2459	3.29	Winter
6/15/2002	02-2460	5.73	Winter
6/15/2002	02-2465	6.35	Winter
6/15/2002	02-2472	3.06	Winter
6/15/2002	02-5581	2.53	Winter
6/15/2002	02-5582	2.19	Winter
6/15/2002	02-5583	2.71	Winter
6/15/2002	02-5587	4.10	Winter
6/15/2002	02-5589	2.65	Winter
6/15/2002	02-5590	2.82	Winter
6/15/2002	02-5595	3.12	Winter
6/16/2002	02-2480	5.88	Winter
6/16/2002	02-2487	1.37	Winter
6/16/2002	02-2496	5.85	Winter
6/16/2002	02-2497	0.41	Winter
6/18/2002	02-2503	6.45	Winter
6/18/2002	02-2506	6.03	Winter
6/18/2002	02-2508	8.98	Winter
6/18/2002	02-2513	4.20	Winter
6/18/2002	02-2519	8.93	Winter
6/18/2002	02-2520	8.11	Winter
6/18/2002	02-2524	7.52	Winter
6/18/2002	02-5604	4.33	Winter
6/21/2002	02-2550	3.00	Winter
6/21/2002	02-2551	3.26	Winter
6/21/2002	02-2552	9.30	Winter
6/21/2002	02-2559	8.76	Winter
6/21/2002	02-2562	4.36	Winter
6/21/2002	02-2569	8.67	Winter
6/21/2002	02-2570	6.52	Winter
6/21/2002	02-2575	5.61	Winter
6/21/2002	02-2581	7.80	Winter
6/21/2002	02-2584	9.97	Winter
6/21/2002	02-2585	3.81	Winter
6/21/2002	02-2590	7.93	Winter
6/21/2002	02-2592	8.83	Winter
6/21/2002	02-5633	4.87	Winter
6/21/2002	02-5634	2.49	Winter

Collection Date	Sample Number	LOD Score	GeneticCall
6/21/2002	02-5638	4.03	Winter
6/22/2002	02-5654	3.95	Winter
6/24/2002	02-2622	4.21	Winter
6/24/2002	02-2636	4.93	Winter
6/24/2002	02-5661	3.06	Winter
6/25/2002	02-2644	5.62	Winter
6/25/2002	02-2647	9.33	Winter
6/25/2002	02-2654	4.43	Winter
6/25/2002	02-2657	7.36	Winter
6/25/2002	02-2660	5.24	Winter
6/25/2002	02-2663	7.43	Winter
6/25/2002	02-2667	8.18	Winter
6/25/2002	02-2670	6.72	Winter
6/25/2002	02-2671	8.03	Winter
6/25/2002	02-2678	3.22	Winter
6/25/2002	02-5663	2.05	Winter
6/25/2002	02-5666	2.60	Winter
6/25/2002	02-5668	4.87	Winter
6/25/2002	02-5673	2.86	Winter
6/25/2002	02-5674	4.68	Winter
6/25/2002	02-5677	2.44	Winter
6/25/2002	02-5679	2.67	Winter
6/27/2002	02-2685	9.46	Winter
6/27/2002	02-2686	7.38	Winter
6/27/2002	02-2690	3.54	Winter
6/27/2002	02-2695	2.81	Winter
6/27/2002	02-2700	6.72	Winter
6/27/2002	02-5686	2.04	Winter
6/27/2002	02-5691	3.81	Winter
6/27/2002	02-5699	5.02	Winter
6/30/2002	02-2734	4.59	Winter
6/30/2002	02-2740	4.69	Winter
6/30/2002	02-2744	3.90	Winter
6/30/2002	02-2749	3.12	Winter
6/30/2002	02-2761	4.20	Winter
6/30/2002	02-2765	10.25	Winter
6/30/2002	02-2766	6.74	Winter
6/30/2002	02-2767	6.12	Winter
6/30/2002	02-2769	4.59	Winter
6/30/2002	02-5726	6.65	Winter
6/30/2002	02-5727	5.49	Winter
6/30/2002	02-5728	9.50	Winter

Collection Date	Sample Number	LOD Score	GeneticCall
7/1/2002	02-5736	4.19	Winter
7/3/2002	02-2801	3.38	Winter
7/3/2002	02-2803	2.65	Winter
7/3/2002	02-2805	5.10	Winter
7/3/2002	02-2809	2.12	Winter
7/3/2002	02-5742	7.49	Winter
7/3/2002	02-5750	1.32	Winter
7/3/2002	02-5751	2.36	Winter
7/3/2002	02-5760	9.08	Winter
7/3/2002	02-5761	4.54	Winter
7/3/2002	02-5763	3.75	Winter
7/3/2002	02-5768	2.30	Winter
7/3/2002	02-5769	4.92	Winter
7/3/2002	02-5776	1.67	Winter
7/3/2002	02-5781	6.72	Winter
7/4/2002	02-2840	4.65	Winter
7/4/2002	02-2859	3.62	Winter
7/4/2002	02-5793	9.45	Winter
7/6/2002	02-2902	3.47	Winter
7/6/2002	02-2905	3.03	Winter
7/6/2002	02-5808	6.53	Winter
7/6/2002	02-5815	4.00	Winter
7/6/2002	02-5818	7.49	Winter
7/6/2002	02-5820	5.69	Winter
7/6/2002	02-5821	3.69	Winter
7/6/2002	02-5830	8.92	Winter
7/7/2002	02-5831	3.00	Winter
7/9/2002	02-2949	0.32	Winter
7/9/2002	02-2952	3.92	Winter
7/9/2002	02-2959	3.17	Winter
7/9/2002	02-2965	4.92	Winter
7/9/2002	02-2972	3.23	Winter
7/9/2002	02-5843	7.40	Winter
7/9/2002	02-5852	8.93	Winter
7/9/2002	02-5853	8.90	Winter
7/9/2002	02-5856	5.68	Winter
7/9/2002	02-5863	6.84	Winter
7/10/2002	02-3035	4.21	Winter
7/10/2002	02-5872	9.10	Winter
7/12/2002	02-3040	4.43	Winter
7/12/2002	02-3050	2.82	Winter
7/12/2002	02-3072	3.52	Winter

Collection Date	Sample Number	LOD Score	GeneticCall
7/12/2002	02-5878	2.63	Winter
7/12/2002	02-5879	8.00	Winter
7/12/2002	02-5880	4.95	Winter
7/12/2002	02-5881	2.68	Winter
7/12/2002	02-5886	6.84	Winter
7/12/2002	02-5891	6.74	Winter
7/12/2002	02-5894	6.29	Winter
7/12/2002	02-5895	7.22	Winter
7/13/2002	02-5897	6.96	Winter
7/13/2002	02-5899	8.05	Winter
7/13/2002	02-5902	5.08	Winter
7/15/2002	02-3100	4.83	Winter
7/15/2002	02-3111	1.14	Winter
7/15/2002	02-3115	-0.63	Non-Winter
7/15/2002	02-3124	4.54	Winter
7/15/2002	02-3127	3.07	Winter
7/15/2002	02-3130	5.10	Winter
7/15/2002	02-3131	2.31	Winter
7/15/2002	02-3140	5.78	Winter
7/15/2002	02-3141	4.05	Winter
7/15/2002	02-5915	2.26	Winter
7/15/2002	02-5920	6.30	Winter
7/15/2002	02-5925	2.57	Winter
7/15/2002	02-5933	3.15	Winter
7/15/2002	02-5936	9.33	Winter
7/15/2002	02-5939	6.83	Winter
7/15/2002	02-5944	6.66	Winter
7/16/2002	02-5948	6.52	Winter
7/16/2002	02-5949	7.45	Winter
7/16/2002	02-5955	6.93	Winter
7/18/2002	02-3181	3.92	Winter
7/18/2002	02-3187	4.24	Winter
7/18/2002	02-3193	4.70	Winter
7/18/2002	02-3199	3.29	Winter
7/18/2002	02-3212	2.47	Winter
7/18/2002	02-5957	6.90	Winter
7/18/2002	02-5959	6.83	Winter
7/18/2002	02-5964	1.93	Winter
7/18/2002	02-5975	8.80	Winter
7/18/2002	02-5976	4.71	Winter
7/18/2002	02-5977	1.51	Winter
7/21/2002	02-3249	1.89	Winter

Collection Date	Sample Number	LOD Score	GeneticCall
7/21/2002	02-3256	2.54	Winter
7/21/2002	02-3257	7.07	Winter
7/21/2002	02-3258	7.94	Winter
7/21/2002	02-3259	2.84	Winter
7/21/2002	02-3260	9.42	Winter
7/21/2002	02-3264	8.59	Winter
7/21/2002	02-3265	6.50	Winter
7/21/2002	02-5992	5.10	Winter
7/21/2002	02-6000	4.75	Winter
7/22/2002	02-3274	7.01	Winter
7/24/2002	02-3279	8.80	Winter
7/24/2002	02-3284	9.19	Winter
7/24/2002	02-3288	9.19	Winter
7/24/2002	02-3291	4.86	Winter
7/24/2002	02-3297	2.81	Winter
7/24/2002	02-6004	6.07	Winter
7/24/2002	02-6007	4.90	Winter
7/24/2002	02-6008	2.26	Winter
7/24/2002	02-6009	6.98	Winter
7/24/2002	02-6010	1.85	Winter
7/24/2002	02-6012	6.23	Winter
7/25/2002	02-3308	4.66	Winter
7/27/2002	02-3324	6.29	Winter
7/27/2002	02-3328	3.03	Winter
7/27/2002	02-6024	3.56	Winter
7/27/2002	02-6027	2.78	Winter
7/30/2002	02-3348	7.93	Winter
7/30/2002	02-3349	3.98	Winter
7/30/2002	02-6032	4.97	Winter
7/30/2002	02-6035	6.10	Winter
7/30/2002	02-6037	3.76	Winter
8/2/2002	02-3363	3.90	Winter
8/2/2002	02-3368	7.34	Winter
8/2/2002	02-3369	4.82	Winter
8/2/2002	02-3370	4.81	Winter
8/2/2002	02-3371	4.01	Winter
8/2/2002	02-3372	5.44	Winter
8/2/2002	02-3373	2.25	Winter
8/2/2002	02-3374	5.93	Winter
8/2/2002	02-3375	3.93	Winter
8/2/2002	02-3376	3.72	Winter
8/2/2002	02-3377	6.38	Winter

Collection Date	Sample Number	LOD Score	GeneticCall
8/2/2002	02-3378	10.10	Winter
8/2/2002	02-6041	3.54	Winter
8/2/2002	02-6043	1.47	Winter
8/3/2002	02-3379	5.28	Winter
8/5/2002	02-3384	4.61	Winter
8/5/2002	02-3385	2.66	Winter
8/5/2002	02-6044	8.59	Winter
8/5/2002	02-6045	4.86	Winter
8/5/2002	02-6046	2.36	Winter
8/8/2002	02-3386	3.68	Winter
8/8/2002	02-3388	5.49	Winter
8/8/2002	02-3389	2.38	Winter
8/8/2002	02-3390	5.17	Winter
8/8/2002	02-6047	5.04	Winter
8/8/2002	02-6048	9.90	Winter
8/8/2002	02-6049	3.11	Winter
8/11/2002	02-3392	6.67	Winter
8/11/2002	02-3393	5.37	Winter
8/12/2002	02-3395	4.38	Winter
8/12/2002	02-6050	2.68	Winter
8/12/2002	02-6051	1.78	Winter
8/12/2002	02-6052	9.76	Winter
8/17/2002	02-3397	-3.16	Non-Winter
8/17/2002	02-3398	0.23	Winter
8/17/2002	02-3399	0.96	Winter
8/17/2002	02-3400	6.29	Winter
8/20/2002	02-6053	4.45	Winter
8/21/2002	02-3401	-2.29	Non-Winter
8/23/2002	02-3402	-0.60	Non-Winter
8/26/2002	02-6054	-3.43	Non-Winter
8/26/2002	02-6055	-4.95	Non-Winter
9/12/2002	02-3406	-4.55	Non-Winter
9/19/2002	02-3408	-2.99	Non-Winter
9/19/2002	02-3409	-7.38	Non-Winter
9/19/2002	02-3410	-0.40	Non-Winter

Appendix C. Recovery information for carcasses containing a coded wire tag (CWT). Data includes river mile (RM) of recovery and carcass gender, fork length (FL), condition (see text [Methods] for description), and spawn status. All fish were winter Chinook salmon originating from Livingston Stone National Fish Hatchery. The exception was for CWT code 062659. This fish was a fall Chinook salmon originating from Feather River Fish Hatchery and was the only fish with no visual indication of having attempted to spawn (i.e., it was full of eggs and had no caudal fin erosion).

Collection Date	CWT Code	RM	Sex	FL	Condition	Spawn Status
5/4/2002	0501020905	298	Male	930	Fresh	Unknown
5/4/2002	0501021302	297	Female	760	Non-Fresh	Spawned
5/10/2002	0501021214	299	Female	720	Fresh	Spawned
5/10/2002	0501021302	296.5	Female	730	Non-Fresh	Spawned
5/13/2002	0501021301	300	Female	790	Fresh	Spawned
5/13/2002	0501021307	296.5	Female	730	Fresh	Spawned
5/16/2002	0501021210	296.5	Female	770	Fresh	Spawned
5/16/2002	0501021214	301	Female	780	Fresh	Spawned
5/16/2002	0501021214	300	Female	760	Fresh	Spawned
5/16/2002	0501021302	298	Female	780	Fresh	Spawned
5/19/2002	0501021301	298	Female	770	Non-Fresh	Spawned
5/22/2002	0501021209	296.5	Female	740	Non-Fresh	Spawned
5/22/2002	0501021211	296.5	Male	790	Fresh	Unknown
5/22/2002	0501021303	296.5	Female	810	Non-Fresh	Spawned
5/22/2002	0501021304	299	Female	690	Non-Fresh	Spawned
5/22/2002	0501021304	296.5	Female	750	Fresh	Unspawned
5/22/2002	0501021304	298	Female	720	Non-Fresh	Spawned
5/22/2002	0501021306	296.5	Female	770	Fresh	Spawned
5/25/2002	0501021209	300	Female	820	Fresh	Spawned
5/25/2002	0501021210	300	Female	730	Non-Fresh	Spawned
5/28/2002	0501021302	299	Female	780	Non-Fresh	Spawned
5/28/2002	0501021305	296.5	Female	660	Non-Fresh	Spawned
5/28/2002	0501021306	300	Female	750	Non-Fresh	Spawned
5/29/2002	0501021211	288	Female	720	Non-Fresh	Spawned
5/29/2002	0501021214	288	Female	740	Non-Fresh	Spawned
5/31/2002	0501021205	296.5	Female	720	Fresh	Spawned
5/31/2002	0501021307	296	Male	690	Fresh	Unknown
6/1/2002	0501021214	291	Female	670	Non-Fresh	Spawned
6/3/2002	0501021209	296.5	Female	740	Fresh	Spawned
6/3/2002	0501021302	298	Male	740	Fresh	Unknown
6/3/2002	0501021305	297	Female	760	Non-Fresh	Spawned
6/3/2002	0501021306	298	Female	760	Non-Fresh	Spawned
6/4/2002	0501021209	294	Female	750	Fresh	Spawned
6/4/2002	0501021304	292	Male	780	Non-Fresh	Unknown

Collection Date	CWT Code	RM	Sex	FL	Condition	Spawn Status
6/6/2002	0501021215	296.5	Female	760	Fresh	Spawned
6/6/2002	0501021302	296	Female	710	Fresh	Spawned
6/9/2002	0501021209	300	Female	710	Fresh	Spawned
6/9/2002	0501021213	299	Female	710	Fresh	Spawned
6/9/2002	0501021302	298	Female	770	Non-Fresh	Spawned
6/9/2002	0501021306	299	Male	840	Fresh	Unknown
6/12/2002	0501021211	300	Female	700	Fresh	Spawned
6/12/2002	0501021212	296.5	Female	790	Fresh	Spawned
6/12/2002	0501021215	296.5	Female	780	Non-Fresh	Spawned
6/12/2002	0501021302	296.5	Female	780	Non-Fresh	Spawned
6/15/2002	0501021215	296.5	Female	720	Fresh	Spawned
6/15/2002	0501021302	301	Female	710	Fresh	Spawned
6/15/2002	0501021303	296.5	Female	810	Non-Fresh	Spawned
6/15/2002	0501021304	299	Female	700	Non-Fresh	Spawned
6/15/2002	0501021305	296.5	Female	740	Fresh	Spawned
6/15/2002	0501021306	299	Female	740	Non-Fresh	Spawned
6/18/2002	0501021215	296.5	Female	760	Fresh	Spawned
6/18/2002	0501021304	295	Female	750	Fresh	Spawned
6/21/2002	0501021208	296.5	Female	780	Fresh	Spawned
6/21/2002	0501021208	298	Female	710	Non-Fresh	Spawned
6/21/2002	0501021209	296.5	Female	770	Non-Fresh	Spawned
6/21/2002	0501021301	299	Female	700	Non-Fresh	Spawned
6/21/2002	0501021302	299	Female	810	Non-Fresh	Spawned
6/21/2002	0501021304	301	Female	710	Fresh	Spawned
6/21/2002	0501021304	295	Female	730	Fresh	Spawned
6/21/2002	0501021304	296.5	Female	750	Non-Fresh	Spawned
6/21/2002	0501021304	296.5	Female	780	Non-Fresh	Spawned
6/21/2002	0501021305	299	Female	700	Non-Fresh	Spawned
6/21/2002	0501021305	298	Female	740	Non-Fresh	Spawned
6/21/2002	0501021307	296.5	Female	660	Non-Fresh	Spawned
6/21/2002	0501021307	296.5	Female	660	Non-Fresh	Spawned
6/21/2002	0501030205	296.5	Male	560	Non-Fresh	Unknown
6/22/2002	0501021301	294	Female	780	Fresh	Spawned
6/25/2002	0501020812	300	Female	780	Fresh	Spawned
6/25/2002	0501021209	299	Female	720	Non-Fresh	Spawned
6/25/2002	0501021215	300	Female	730	Non-Fresh	Spawned
6/25/2002	0501021215	299	Female	770	Fresh	Spawned
6/25/2002	0501021303	301	Female	740	Non-Fresh	Spawned
6/25/2002	0501021303	300	Female	780	Fresh	Spawned
6/25/2002	0501021303	300	Female	790	Fresh	Spawned
6/25/2002	0501021304	299	Female	620	Fresh	Spawned
6/25/2002	0501021305	300	Female	780	Fresh	Spawned

Collection Date	CWT Code	RM	Sex	FL	Condition	Spawn Status
6/25/2002	0501021306	296.5	Female	780	Fresh	Spawned
6/25/2002	0501021306	298	Female	760	Fresh	Spawned
6/25/2002	0501021307	299	Female	720	Fresh	Spawned
6/25/2002	0501030306	296	Female	500	Non-Fresh	Spawned
6/27/2002	0501021206	297	Female	730	Non-Fresh	Spawned
6/30/2002	0501021210	296.5	Female	760	Non-Fresh	Spawned
6/30/2002	0501021210	296.5	Female	730	Non-Fresh	Spawned
6/30/2002	0501021302	296.5	Female	730	Fresh	Spawned
6/30/2002	0501021305	297	Female	730	Non-Fresh	Spawned
6/30/2002	0501021306	297	Female	780	Non-Fresh	Spawned
6/30/2002	0501021306	300	Female	760	Non-Fresh	Spawned
6/30/2002	0501021307	300	Female	710	Non-Fresh	Spawned
7/3/2002	0501021214	298	Female	770	Fresh	Partial
7/3/2002	0501021304	296.5	Female	780	Fresh	Spawned
7/3/2002	0501021305	300	Female	630	Non-Fresh	Unspawned
7/3/2002	0501021306	299	Female	730	Non-Fresh	Spawned
7/3/2002	0501021306	297	Female	790	Fresh	Spawned
7/3/2002	0501021307	296.5	Female	830	Fresh	Spawned
7/3/2002	0501030205	297	Male	650	Fresh	Unknown
7/4/2002	0501021207	294	Male	780	Fresh	Unknown
7/4/2002	0501030306	288	Male	510	Fresh	Unknown
7/6/2002	0501021207	296.5	Female	780	Non-Fresh	Spawned
7/6/2002	0501021213	299	Female	700	Non-Fresh	Spawned
7/6/2002	0501021213	296.5	Female	640	Non-Fresh	Spawned
7/6/2002	0501021213	296.5	Female	670	Non-Fresh	Spawned
7/6/2002	0501021215	300	Female	760	Non-Fresh	Spawned
7/6/2002	0501021304	299	Female	710	Fresh	Spawned
7/6/2002	0501021304	299	Female	740	Non-Fresh	Spawned
7/7/2002	0501030408	295	Male	630	Fresh	Unknown
7/9/2002	0501021207	300	Female	760	Fresh	Spawned
7/9/2002	0501021209	296.5	Male	580	Fresh	Unknown
7/9/2002	0501021301	299	Female	740	Fresh	Spawned
7/9/2002	0501021305	296.5	Female	750	Unknown	Spawned
7/9/2002	0501021307	296.5	Female	740	Unknown	Spawned
7/9/2002	0501030201	301	Female	730	Non-Fresh	Spawned
7/10/2002	0501030308	289	Male	540	Fresh	Unknown
7/12/2002	0501021206	300	Female	740	Fresh	Spawned
7/12/2002	0501021206	296.5	Female	750	Fresh	Spawned
7/12/2002	0501021215	299	Female	850	Fresh	Spawned
7/12/2002	0501021215	299	Female	780	Fresh	Spawned
7/15/2002	0501021205	296.5	Female	770	Fresh	Spawned
7/15/2002	0501021211	298	Female	660	Non-Fresh	Spawned

Collection Date	CWT Code	RM	Sex	FL	Condition	Spawn Status
7/15/2002	0501021212	296.5	Female	690	Fresh	Spawned
7/15/2002	0501021212	296.5	Female	780	Fresh	Spawned
7/15/2002	0501021213	296.5	Female	750	Fresh	Spawned
7/15/2002	0501021305	297	Female	720	Non-Fresh	Spawned
7/15/2002	0501021306	296.5	Female	760	Fresh	Spawned
7/15/2002	0501030207	296.5	Male	550	Fresh	Unknown
7/15/2002	0501030302	299	Male	520	Fresh	Unknown
7/15/2002	0501030307	296.5	Male	470	Fresh	Unknown
7/15/2002	0501030401	296	Male	500	Non-Fresh	Unknown
7/16/2002	0501030308	291	Male	520	Non-Fresh	Unknown
7/16/2002	0501030308	294	Male	530	Fresh	Unknown
7/18/2002	0501021207	296.5	Female	650	Non-Fresh	Spawned
7/18/2002	0501021208	299	Female	690	Non-Fresh	Spawned
7/18/2002	0501021212	297	Female	720	Non-Fresh	Spawned
7/18/2002	0501021307	299	Female	740	Non-Fresh	Spawned
7/18/2002	0501030206	296	Male	530	Non-Fresh	Unknown
7/21/2002	0501021207	299	Female	690	Fresh	Spawned
7/24/2002	0501021305	299	Female	700	Non-Fresh	Spawned
7/24/2002	0501021307	296.5	Female	720	Fresh	Spawned
7/25/2002	062659	294	Female	710	Fresh	Unspawned
7/27/2002	0501021305	299	Female	730	Non-Fresh	Spawned
7/27/2002	0501021305	300	Female	720	Fresh	Spawned
8/5/2002	0501021307	299	Female	690	Fresh	Spawned

Appendix D. Average length in millimeters (FL), average weight in grams (WT), and number of winter Chinook salmon released from Livingston Stone National Fish Hatchery. Coded wire tag (CWT) code 0501021307 was used for the progeny of captive broodstock held at the University of California-Davis Bodega Bay Marine Laboratory. Number released is reported for each CWT as (1) number released with an adipose fin clip (C) and CWT (T), (2) C and no CWT (NT), (3) No adipose fin clip (NC) and a T, and (4) NC and NT. For corresponding brood year (BY) for each CWT code see Table 1. All fish were released at Lake Redding Park.

					Number Released			
BY	CWT Code	FL	Weight	Release Date	C/T	C/NT	NC/T	NC/NT
1998	0501020811	82	569	1/28/1999	10,434	907	0	0
1998	0501020812	70	340	1/28/1999	10,243	52	105	52
1998	0501020813	74	423	1/28/1999	9,636	300	50	0
1998	0501020814	86	667	1/28/1999	7,128	299	0	0
1998	0501020815	82	559	1/28/1999	7,207	73	37	0
1998	0501020901	76	425	1/28/1999	8,035	82	41	0
1998	0501020902	75	448	1/28/1999	7,576	77	38	0
1998	0501020903	78	448	1/28/1999	6,889	35	0	0
1998	0501020904	88	767	1/28/1999	6,341	196	0	0
1998	0501020905	84	614	1/28/1999	6,105	1,688	0	0
1998	0501020906	84	640	1/28/1999	9,364	551	100	0
1998	0501020907	70	362	1/28/1999	9,262	341	146	0
1998	0501020908	70	398	1/28/1999	7,910	416	0	0
1998	0501020909	73	368	1/28/1999	7,403	231	77	0
1998	0501020910	84	540	1/28/1999	5,070	158	26	0
1998	0501020911	74	454	1/28/1999	7,869	328	0	0
1998	0501020912	78	523	1/28/1999	6,167	191	0	0
1998	0501020913	91	776	1/28/1999	5,414	110	0	0
1998	0501020914	89	806	1/28/1999	5,901	30	0	0
1998	0501020915	87	643	1/28/1999	2,788	72	0	0

BY	CWT Code	FL	Weight	Release Date	Number Released C/T	C/NT	NC/T	NC/NT
1998	0501021001	87	792	1/28/1999	353	4	0	0
1999	0501021205	75	395	1/27/2000	860	4	4	0
1999	0501021206	74	440	1/27/2000	1,180	18	6	0
1999	0501021207	74	479	1/27/2000	1,283	20	7	0
1999	0501021208	76	522	1/27/2000	809	12	0	0
1999	0501021209	84	669	1/27/2000	1,000	21	10	0
1999	0501021210	79	570	1/27/2000	1,258	26	20	0
1999	0501021211	98	1054	1/27/2000	1,549	8	0	0
1999	0501021212	103	1341	1/27/2000	1,145	0	0	0
1999	0501021213	89	892	1/27/2000	1,730	26	0	0
1999	0501021214	92	968	1/27/2000	1,545	0	0	0
1999	0501021215	96	1108	1/27/2000	1,199	6	0	0
1999	0501021301	101	1275	1/27/2000	1,574	57	0	0
1999	0501021302	98	1171	1/27/2000	2,115	65	0	0
1999	0501021303	100	1255	1/27/2000	1,993	0	10	0
1999	0501021304	101	1231	1/27/2000	1,716	0	0	0
1999	0501021305	89	808	1/27/2000	2,125	21	0	0
1999	0501021306	98	1305	1/27/2000	3,054	46	0	0
1999	0501021307	69	370	1/27/2000	4,232	65	22	0
2000	0501030107	81	587	2/1/2001	8,023	124	83	41
2000	0501030108	82	601	2/1/2001	5,284	220	0	0
2000	0501030109	77	507	2/1/2001	5,550	172	0	0
2000	0501030201	72	408	2/1/2001	5,429	347	0	0
2000	0501030202	81	595	2/1/2001	5,241	395	0	0
2000	0501030203	81	580	2/1/2001	6,403	164	0	0
2000	0501030204	80	556	2/1/2001	5,586	203	0	0

BY	CWT Code	FL	Weight	Release Date	Number Released			
					C/T	C/NT	NC/T	NC/NT
2000	0501030205	82	602	2/1/2001	6,166	158	0	0
2000	0501030206	75	475	2/1/2001	6,901	70	0	0
2000	0501030207	78	528	2/1/2001	6,013	0	0	0
2000	0501030208	79	551	2/1/2001	5,381	54	0	0
2000	0501030209	77	510	2/1/2001	5,634	147	88	0
2000	0501030301	81	580	2/1/2001	5,500	56	0	0
2000	0501030302	79	534	2/1/2001	5,747	59	59	0
2000	0501030303	76	479	2/1/2001	5,966	91	0	0
2000	0501030304	77	516	2/1/2001	5,829	29	29	0
2000	0501030305	76	491	2/1/2001	5,333	27	0	0
2000	0501030306	83	631	2/1/2001	5,325	137	0	0
2000	0501030307	83	639	2/1/2001	5,007	102	0	0
2000	0501030308	72	413	2/1/2001	5,268	108	0	0
2000	0501030309	83	627	2/1/2001	4,798	48	0	0
2000	0501030401	80	561	2/1/2001	5,126	131	0	0
2000	0501030402	86	709	2/1/2001	4,826	98	0	0
2000	0501030403	84	645	2/1/2001	5,319	164	0	0
2000	0501030404	86	710	2/1/2001	4,439	161	0	0
2000	0501030405	84	656	2/1/2001	5,435	168	0	0
2000	0501030406	85	685	2/1/2001	4,763	73	0	0
2000	0501030407	81	582	2/1/2001	4,603	23	47	0
2000	0501030408	81	590	2/1/2001	4,666	23	0	0
2000	0501030409	87	730	2/1/2001	2,637	110	0	0